Biology of Blood and Marrow Transplantation 10:269-275 (2004)

1083-8791/04/1004-0006$30.00/0
doi:10.1016/j.bbmt.2003.12.003

Racial Diversity with High Nucleated Cell Counts and CD34 Counts Achieved in a National Network of Cord Blood Banks

Karen K. Ballen,[1,2] Joanne Kurtzberg,[3,4] Thomas A. Lane,[5] Bruce R. Lindgren,[6] John P. Miller,[6,7] Denis Nagan,[6] Bruce Newman,[8] Neil Rupp,[5,9] N. Rebecca Haley[9]

[1]American Red Cross Cord Blood Program, Worcester, Massachusetts; [2]Massachusetts General Hospital, Boston, Massachusetts; [3]American Red Cross Cord Blood Program, Durham, North Carolina; [4]Duke University Medical Center, Durham, North Carolina; [5]American Red Cross Cord Blood Program, Portland, Oregon; [6]University of Minnesota, Minneapolis, Minnesota; [7]American Red Cross Cord Blood Program, St. Paul, Minnesota; [8]American Red Cross Cord Blood Program, Detroit, Michigan; [9]American Red Cross Cord Blood Program, Arlington, Virginia

Correspondence and reprint requests: Karen K. Ballen, MD, Hematology/Oncology Division, Massachusetts General Hospital, 100 Blossom St., Cox 640, Boston, MA 02114 (e-mail: kballen@partners.org).

Received August 18, 2003; accepted December 10, 2003

ABSTRACT

Banked, unrelated, partially HLA-matched, umbilical cord blood is an alternative stem cell source for patients in need of transplantation therapy who lack traditionally matched donors. A presumed advantage of cord blood is the ability to increase recruitment of donors of minority ethnic backgrounds. The American Red Cross Cord Blood Program was established in 1999 with 6 banks and 10 collection sites throughout the country. Cord blood donors self-report racial designations on questionnaires, and donor race was collected from each site. Postprocessing nucleated cell counts and $CD34^+$ counts were obtained on the cord blood units, and results from each racial group (white, black, Asian, Hispanic, and Native American) were compared in the natural logarithmic scale by using analysis of variance. A total of 18878 donors consented: 64% white, 16% black, 12% Hispanic, 4% Asian, 1% Native American, and 3% other. The Detroit area consented the highest percentage of black donors (87%), San Diego consented the highest percentage of Hispanic donors (59%), and Oakland consented the highest percentage of Asian donors (15%). Seven thousand eight hundred sixty-six cord blood units have been banked for transplantation. The mean preprocessing nucleated cell count was 1220×10^6 (range, $327\text{-}7300 \times 10^6$). There was no difference among racial groups when controlled for site ($P = .395$). The mean $CD34^+$ count was 3.28×10^6. Blacks had a significantly lower $CD34^+$ count than the other racial/ethnic groups in the Midwest, Northwest, and North Carolina collection sites. A racially diverse cord blood bank can be achieved. Nucleated cell counts were similar among the different racial/ethnic groups. $CD34^+$ counts were lower for blacks in some collection sites.

KEY WORDS

Cord blood • Minority • Donor recruitment

INTRODUCTION

Myeloablative chemotherapy with or without radiotherapy followed by allogeneic bone marrow or stem cell transplantation has been shown to be an effective treatment for several cancers and genetic disorders [1-3]. Unfortunately, the availability of transplantation is limited by the need for a compatible donor source, and only 30% of patients have a suitably matched sibling donor [4]. Several international registries of bone marrow donors, including the Anthony Nolan Registry, the Caitlin Raymond International Registry, and the National Marrow Donor Program (NMDP), were established to provide a stem cell donor source for patients without family donors [5]. The NMDP has 4,794,523 donors, of whom 1,259,186 are classified as nonwhite or minority [6].

Umbilical cord blood has been shown to contain sufficient progenitor cells to provide durable engraft-

ment [7]. The first related cord blood transplantation was performed in France in 1988 in a patient with Fanconi's anemia [8]. The first unrelated cord blood transplant was performed at Duke University in 1993 [9]. Results in children who have undergone transplantation with unrelated cord blood units show a 30% to 80% disease-free survival, depending on disease and age [10-13]. Umbilical cord blood transplantation has been extended to adult patients, with disease-free survival rates ranging from 25% to 53% [14-16]. The cell dose infused is an important prognostic factor in many of these studies; patients who receive a higher nucleated cell count per kilogram or more $CD34^+$ cells per kilogram experience improved survival [11,12,15].

To accommodate the clinical need, banks of cryopreserved umbilical cord blood cells have been established worldwide [10,17-21]. A reported goal of many cord blood banks is to provide a racially and ethnically diverse donor pool to ensure equitable access to transplant donors. However, early efforts in cord blood banking showed that there was no improvement in the recruitment of minority cord blood donors over minority unrelated bone marrow donors in 4 of the 5 geographic areas studied [22].

In this study, we examined the racial/ethnic composition of cord blood donors in the American Red Cross (ARC) Cord Blood Program and compared the nucleated cell counts and $CD34^+$ cells achieved in the different racial/ethnic groups.

MATERIALS AND METHODS

Cord Blood Donors

Cord blood donors were consented and enrolled according to the procedures of the ARC Cord Blood Program [23]. The ARC Cord Blood Program, established in 1999, is a national network of cord blood banks. Donors were recruited from January 1999 to September 2002. Maternal donors were recruited in 10 different collection locations: Florence, AL; Oakland and San Diego, CA; Silver Spring, MD; Worcester, MA; Detroit, MI; St. Paul, MN; Great Falls, MT; Durham, NC; and Portland, OR. All donors signed a consent form approved by the institutional review board of their participating hospital. Mothers self-reported racial/ethnic background on a medical history and donor questionnaire. All areas used a similar maternal questionnaire. Data used for this study are the maternal race/ethnicity answers.

Laboratory Data

Cord blood units that met standard processing criteria were cryopreserved and frozen, according to the techniques of Rubinstein et al. [24]. Cord blood cells were processed in 6 processing laboratories of the ARC Cord Blood Program (San Diego, CA; Worcester, MA; Detroit, MI; St. Paul, MN; Durham, NC; and Portland, OR). Cell counts were performed with standard Coulter counters. Nucleated red blood cells were counted as part of the nucleated cells, and a comment was made to the prospective transplant team when the nucleated red blood cell count was >20%. In the Detroit program, the white blood cell count was corrected for the nucleated red blood cells. Differentials were performed manually by using a Wright stained smear [23]. Cell viability was assessed by Trypan blue dye viability or acridine orange and/or propidium iodide staining; cord blood units with <80% viability were excluded from the search. $CD34^+$ cells were analyzed by using one of the International Society for Hematotherapy and Graft Engineering methods [25,26]. All the laboratories used the standard International Society of Hematotherapy and Graft Engineering dual-platform method, except for Duke, which used the ProCOUNT reagent kit (Becton Dickinson, Franklin Lakes, NJ) and software [26]. The minimum standards for processing were 40 mL until July 2001. After July 2001, minimum standards to begin processing were changed to 80×10^8 nucleated cells.

Statistical Analysis

The study population consisted of mothers who consented to donate cord blood. Frequency distributions provided the breakdown of these donors by ethnicity and site. The numbers of cord blood units that were collected, banked, or discarded were also counted for the different racial groups and collection centers. Reasons for cord blood units not being banked included low volume, low total nucleated cell count, positive maternal infectious disease markers, medical history exclusion, or processing laboratory issues. For purposes of statistical analyses, Native Americans were combined with the racial classification of "other." The χ^2 test was used to compare the number of donors and units banked between ethnic groups. These tests were performed with all cord units and also separately for each collection site.

Preprocessing nucleated cell counts, postprocessing nucleated cell counts, and CD34 counts had distributions that were distinctly skewed to the right. Therefore, these cell counts were analyzed in the natural logarithmic scale. The mean values presented in Results, including the tables and figure, are geometric means. The 2-way analysis of variance (ANOVA) was used to evaluate the effects of site and ethnicity on the cell counts. If there was a significant interaction between race and site, then each collection site was analyzed separately with a 1-way ANOVA of ethnicity on the number of cells. A P value <.05 was considered statistically significant.

Table 1. *Race/Ethnicity of Consented Mothers*

Race/Ethnicity	n (%)
White	12,089 (64.0)
Black	3029 (16.1)
Asian/Pacific Islander	837 (4.4)
Hispanic	2192 (11.6)
Native American	128 (0.7)
Other	507 (2.2)
Unknown	96 (0.5)

RESULTS

Racial/Ethnic Information on Consenting Mothers

A total of 18878 mothers consented to participate in this study. The racial/ethnic background of these donors is illustrated in Table 1. Sixty-four percent of these mothers were white, 16% were black, 12% were Hispanic, 4% were Asian, and 1% were Native American. Three percent of mothers classified themselves as other. The race/ethnicity was unknown for 96 (0.5%) of those who consented. These mothers who had a missing race were excluded from further analyses.

Racial/Ethnic Information by Collection Site

Table 2 demonstrates the racial/ethnic breakdown of donors by collection site. The small number of Alabama cords, which were processed in Massachusetts, were included with the Massachusetts cords. The Midwest sites included St. Paul, MN, and Detroit, MI. The Northwest sites included Great Falls, MT, and Portland, OR, and the California site covered both Oakland and San Diego. The Capital area refers to the Washington, DC, area. The highest percentage of black donors was recruited in Detroit (87% of donors in this location). San Diego had the highest percentage of Hispanic donors (59%). Fifteen percent of the donors in Oakland were Asian. The highest percentage of Native American donors (3%) was recruited from Montana.

Racial/Ethnic Information on Mothers of Cord Blood Units Banked for Transplantation

There were 15685 (83.5%) mothers who consented to participate in the study and had cord blood units collected; 50% of the collected units (or 42% of the number of consenting mothers) were banked for transplantation. Seven thousand eight hundred sixty-six cord blood units were banked for transplantation. The ethnic/racial composition of the mothers whose units were banked for transplantation was as follows: 69% white, 12% black, 4% Asian, 12% Hispanic, and 1% Native American. The percentage of consenting white donors whose units were banked was 45%, compared with 32% for black donors and 36% for Asian donors ($P < .001$). Figure 1 shows this relatively greater loss of black and Asian donors from consenting mothers to banked units.

The reasons why the cord blood unit could not be banked included low volume (<40 mL of cord blood; 42.1%), low cell count (after July, 2001, $<80 \times 10^8$ nucleated cells; 26.5%), processing laboratory issues (5.2%), medical history exclusion (3.9%), positive infectious disease marker (3.8%), and other (18.5%). The most common reason for discard in the category of positive infectious disease markers was a positive hepatitis serology. Table 3 demonstrates these discard reasons stratified by race/ethnicity. The biggest difference occurred in the category of positive infectious disease markers; Asian donors had the highest percentage (15.7%) compared with the other racial/ethnic groups ($P < .001$), which reflects the known higher hepatitis carrier rate in this population. The volume of the discarded units ranged from a median of 51 mL in whites to 58 mL in Asians.

In addition, there seemed to be site-specific differences (Table 4). For instance, in California, the

Table 2. *Ethnic Breakdown of Cord Blood Units Collected from Consented Mothers by Site**

	Ethnicity					
Site	White	Black	Asian	Hispanic	Native American/Other	Total
Massachusetts	2308 (89.4%)	41 (1.6%)	52 (2.0%)	83 (3.2%)	98 (3.8%)	2582
California						
Oakland	332 (34.6%)	252 (26.3%)	144 (15.0%)	158 (16.5%)	73 (7.6%)	959
San Diego ARC	626 (33.0%)	21 (1.1%)	64 (3.4%)	1126 (59.3%)	63 (3.3%)	1900
Midwest						
St. Paul	2336 (74.7%)	445 (14.2%)	180 (5.8%)	107 (3.4%)	58 (1.9%)	3126
Detroit	94 (9.6%)	849 (87.0%)	6 (0.6%)	21 (2.2%)	6 (0.6%)	976
Northwest						
Portland	2683 (78.5%)	232 (6.8%)	160 (4.7%)	138 (4.0%)	206 (6.0%)	3419
Great Falls	978 (91.2%)	10 (0.9%)	8 (0.8%)	18 (1.7%)	58 (5.4%)	1072
Capital area	985 (53.0%)	490 (26.4%)	127 (6.8%)	212 (11.4%)	44 (2.4%)	1858
Duke ARC	1747 (60.5%)	689 (23.8%)	96 (3.3%)	329 (11.4%)	29 (1.0%)	2890

*Table excludes the cords with missing ethnicity.

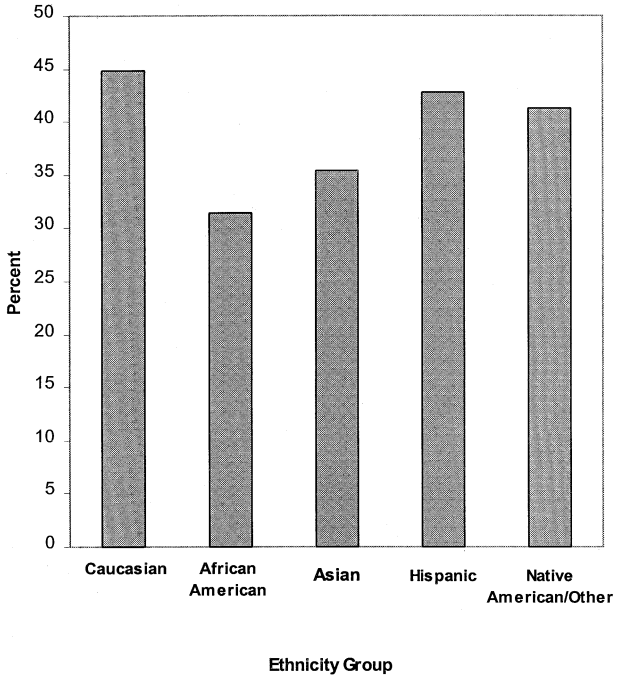

Figure 1. The percentage of consented mothers whose cord units were banked shown by race/ethnicity.

Midwest, the Capital area, the Northwest, and North Carolina, there was a significant difference in the percentage of banked units among the different racial/ethnic groups. The P values here (χ^2 test) represent the equality of percentages across ethnic groups. Only in Massachusetts, which had the highest percentage of white donors, was there no difference in the percentage of banked units among the different racial/ethnic groups.

Nucleated Cell Counts and CD34 Counts

The nucleated cell counts for the entire group separated by racial/ethnic categories are displayed in Table 5. For the entire cohort, the mean preprocessing nucleated cell count was 1220×10^6 (range, 327-7300×10^6). The mean counts ranged from 1159 for blacks to 1242 for whites. The 2-way ANOVA showed no significant effect of ethnicity ($P = .389$); however, there was a difference among collection sites ($P = .013$) and a significant interaction between sites and racial/ethnic groups ($P = .043$). This indicates that, on average, the preprocessing total nucleated cell count was similar among races, although this relationship among races varied greatly from site to site. For example, Asians had the highest average preprocessing total nucleated cell counts in California and the lowest in Washington, DC. Hispanic donors had the lowest cell counts in California but the highest in the Midwest and North Carolina. Evaluating the individual sites separately revealed that only in California and North Carolina were the preprocessing total nucleated cell counts significantly different among the racial/ethnic groups. Because of the large sample size, small differences among groups achieved statistical significance. The percentage difference between the highest and lowest mean cell counts among racial/ethnic categories was only 7.2%.

The statistical findings for volume and postprocessing nucleated cell counts were very similar to those presented previously for the preprocessing nucleated cells. The mean postprocessing nucleated cell count was 946 (range, 180-4550) and showed similar site-specific trends.

The CD34 counts stratified by racial/ethnic classification are outlined in Table 5. The mean $CD34^+$ count for the entire cohort was 3.28×10^6, with a range of 0.09 to 44.51×10^6. The ethnicity, collection site, and interaction effects were significant ($P < .05$). Once again, racial/ethnic groups were compared in a separate analysis for each site. Significant differences in $CD34^+$ cell counts were found among races for the Midwest, Northwest, and North Carolina. At all 3 of these collection sites, blacks had the lowest average value. Unlike the preprocessing nucleated cell counts, the $CD34^+$ counts had a pronounced difference between the minimum and the maximum mean for the ethnic groups. The relative percentage change was 29.7%. This large effect was primarily due to the low average $CD34^+$ counts in blacks.

We also studied the postprocessing nucleated cell count, as outlined in Table 5. Hispanics had the highest mean postprocessing nucleated cell count/volume (11.9×10^6/mL), and blacks had the lowest (11.0×10^6/mL). The percentage difference between these 2

Table 3. *Reason for Discard of Cord Blood Units by Ethnicity*

Variable	Ethnicity				
	White	Black	Asian	Hispanic	Native American/Other
Low volume (<40 mL)	2090 (45.1%)	553 (37.8%)	127 (33.8%)	315 (37.5%)	98 (39.8%)
Positive infectious disease marker	117 (2.5%)	73 (5.0%)	59 (15.7%)	31 (3.7%)	10 (4.1%)
Processing laboratory issues	280 (6.1%)	35 (2.4%)	12 (3.2%)	49 (5.8%)	14 (5.7%)
Medical history exclusion	158 (3.4%)	71 (4.9%)	16 (4.3%)	46 (5.5%)	1 (0.4%)
Low cell count (<80×10^8 NC)	1138 (24.6%)	448 (30.6%)	83 (22.1%)	265 (31.5%)	68 (27.8%)
Other	848 (18.3%)	282 (19.3%)	79 (21.0%)	135 (16.1%)	55 (22.2%)

NC indicates nucleated cells.

Table 4. *Percentage of Cord Blood Units Banked by Ethnicity*

Site	Ethnicity					
	White (%)	Black (%)	Asian (%)	Hispanic (%)	Native American/Other (%)	*P* Value (χ^2 test)
Massachusetts	39.3	26.8	40.4	31.3	35.7	.271
California	40.9	19.8	34.1	45.1	33.1	<.001
Midwest	44.8	29.0	30.7	33.6	42.2	<.001
Northwest	44.7	33.1	41.1	39.1	41.7	.005
Capital area	29.1	17.1	19.7	23.1	50.0	<.001
North Carolina	63.6	51.1	56.3	53.2	65.5	<.001
Overall	44.9	31.6	35.5	42.6	40.6	<.001

groups was only 8.0%, similar to the preprocessing nucleated cell count. The overall mean for all the ethnic/racial groups was 11.6 $\times$ 10^6/mL (range, 3.0-49.4 $\times$ 10^6/mL). The main effects for ethnicity and the collection sites were statistically significant (P = .019 and $P < .001$, respectively). When each site was analyzed individually, only North Carolina was significantly different among racial/ethnic groups. This difference was due to the lower mean value for the blacks compared with the whites.

The standards for processing cord blood units changed in July 2001 to meet a minimum standard for processing of 80 $\times$ 10^8 nucleated cells at all sites. $CD34^+$ cells were analyzed by ethnicity before and after July 2001. Most black donors were enrolled after this date. After July 2001, there was a greater difference in $CD34^+$ cells among the different ethnic groups. The $CD34^+$ cells ranged from 2.64 $\times$ 10^6 in blacks to 3.35 $\times$ 10^6 in whites to 3.86 $\times$ 10^6 in Native Americans and other ethnicities. These results, displayed in Table 6, were statistically significant.

DISCUSSION

Cord blood remains a viable stem cell source, especially for those patients without a matched family or unrelated donor. Because clinical studies have indicated an improvement in survival with the infusion of higher cell doses per kilogram, cord blood banks have attempted to provide cord blood units with high cell doses [11,13,17]. Another goal of cord blood banks is to ensure a racially/ethnically diverse donor pool to accommodate racially/ethnically diverse transplant recipients. However, early reports from the NMDP cord blood banks showed that in 4 of the 5 areas surveyed, minority recruitment was worse in the cord blood program than in the marrow donor center [22]. Other banks may have had more success with recruitment of minority cord blood donors [10,27,28]. For example, the Cord Blood Transplantation trial recently reported that 22% of their cord blood units were collected from Hispanic donors, 15% from black donors, and 8% from Asian donors [28]. In our current study, we achieved racial/ethnic diversity by establishing cord blood collection sites in hospitals with a diverse maternal population.

Studies of solid organ donation report less interest in donation among blacks [29,30]. The Task Force on Organ Transplantation has been addressing this issue by fostering communication among families and caregivers; the donor rate for minorities increased from 16% in 1988 to 23% in 1995 among cadaver donors [31]. For living donors, the donation rate increased from 24% to 28% in the same period.

In this study, we have shown that a racially/ethnically diverse donor pool can be achieved in a national network of cord blood banks: the ARC Cord Blood Program. We did not compare our results from cord blood donors with those of marrow donors in this

Table 5. *Data by Ethnicity (Mean Values)*

Variable	n	Mean	95% Confidence Interval
Preprocessing total nucleated cell count (× 10^6)			
White	5414	1242.2	1230.1–1254.5
Black	957	1159.2	1132.3–1186.7
Asian	296	1216.9	1169.6–1266.0
Hispanic	932	1163.6	1138.5–1189.2
Other	258	1212.7	1158.4–1269.6
$CD34^+$ Count (× 10^6)			
White	5408	3.37	3.31–3.44
Black	957	2.73	2.60–2.87
Asian	296	3.55	3.27–3.85
Hispanic	929	3.19	3.05–3.33
Other	258	3.51	3.20–3.85
Postprocessing total nucleated cell count (× 10^6)/volume (mL)			
White	5417	11.6	11.5–11.7
Black	957	11.0	10.8–11.2
Asian	296	11.7	11.3–12.0
Hispanic	932	11.9	11.7–12.1
Other	258	11.6	11.2–12.0

Table 6. *$CD34^+$ Count (× 10^6) by Ethnicity by Process Date*

Ethnicity	Before July 1, 2001		After July 1, 2001	
	n	Geometric Mean	n	Geometric Mean
White	1987	3.39	3421	3.35
Black	160	3.22	797	2.64
Asian or Pacific Islander	82	3.29	214	3.67
Hispanic	339	2.97	590	3.32
Native American/other	98	3.00	160	3.86

Site $\times$ ethnicity interaction, P = .032.

study. As expected, certain collection sites were more likely to recruit donors from a different racial/ethnic group; Detroit, for example, had the highest percentage of black donors in the program. San Diego had the highest percentage of Hispanic donors in the program. Other cord blood banks are also increasing their minority recruitment; the Cord Blood Transplantation study recently reported that of the first 179 transplantations facilitated by their banks, 33% of the recipients and 34% of the donors were nonwhite [28]. This increase in the number of minority donors may reflect greater awareness and availability of resources for minority recruitment. The increase in minority donors may also represent a greater willingness to participate because of less risk of cord blood versus bone marrow or peripheral blood stem cell donation.

Our data did show variation among the different racial/ethnic groups, particularly for $CD34^+$ counts. In 3 collection areas (the Midwest, the Northwest, and North Carolina), blacks had significantly lower $CD34^+$ counts. In all 7 locations, the percentage of cord blood units stored from black donors was always the lowest of all the races. This difference may reflect difference in $CD34^+$ measurements. It is possible that biologic factors related to delivery or socioeconomic differences may also be involved; however, these issues were not addressed in this study. These data suggest that even greater recruitment efforts are needed for black donors to provide cord blood units with high $CD34^+$ counts. Collection of sufficient cord blood units from black donors will require additional resources for 2 reasons: (1) fewer of the mothers who consent will have cord units banked (45% versus 32%) and (2) more cords may need to be collected to achieve a high CD34 count. Additional efforts will also be needed to recruit Asian donors because of high rates of deferral as a result of positive infectious disease markers.

The study is limited by site-specific differences. A preliminary study among ARC cord blood banks tested identical cord blood samples in different processing laboratories of the ARC Cord Blood Program. Despite use of similar methods, there was variation in cell counts and CD34 counts among the different processing laboratories. This difference was greatest for CD34 counts, with up to a 3-fold variation in 1 exercise [32]. In 1 exercise that used aliquots of the same frozen sample, $CD34^+$ results ranged from 15 cells per microliter in the Portland laboratory to 63 cells per microliter in the Minnesota laboratory. Therefore, our results were controlled for site and should be interpreted cautiously. There may be similar site-specific differences in other large cord blood programs with more than 1 processing laboratory [19,21].

Another limitation of the study is the use of self-reported racial and/or ethnic designations based on a screening questionnaire filled out by the mother before donation. We also collect information (if available) on the putative father of the baby, but this information was not analyzed in this study. In addition, the terms used, eg, "Caucasian" and "Hispanic," compromise a wide group of donors with potentially different ethnic origins. No attempt was made to confirm the accuracy of the self-reported racial designations. A survey of Hispanics that used surnames, medical records, and self-identification found that many self-identified Hispanics were identified incorrectly (sensitivity of 68%) [33]. A recent review summarizes the difficulty of studying race and ethnicity in medical research [34].

Our study did not examine the various HLA types among the different racial/ethnic groups. The frequencies of rare antigens and haplotypes were not addressed in this study but form the basis for future work. In some reports, minorities represent 30% of cord blood transplant recipients [9,28]. Presumably, these patients did not have an alternative acceptable donor source. A recent report from the International Bone Marrow Transplant Registry indicated that survival after HLA-identical sibling transplantation was lower for Hispanic patients than for whites [35]. An analogous study has not been performed for patients receiving cord blood transplants.

In summary, a diverse population of cord blood donors can be achieved in a national network of cord blood banks. In some sites, cord blood units from black donors had lower CD34 counts. Future studies will address the cord blood outcomes of the various racial/ethnic groups.

REFERENCES

1. Thomas ED, Clift RA, Fefer A, et al. Marrow transplantation for the treatment of chronic myelogenous leukemia. *Ann Intern Med.* 1986;104:155-163.
2. Krivit W, Whitley CB. Bone marrow transplantation for genetic diseases. *N Engl J Med.* 1987;316:1085-1090.
3. Lucarelli G, Galimberti M, Polchi P, et al. Marrow transplantation in patients with advanced thalassemia. *N Engl J Med.* 1987;316:1050-1055.
4. Anasetti C, Amos D, Beatty PG, et al. Effect of HLA compatibility on engraftment of bone marrow transplants to patients with leukemia or lymphoma. *N Engl J Med.* 1987;197:320-325.
5. Kernan NA, Bartsch G, Ash RC, et al. Analysis of 462 transplantations from unrelated donors facilitated by the National Marrow Donor Program. *N Engl J Med.* 1993;328:593-598.
6. National Marrow Donor Program Statistics, Minority Facts and Figures, 2002.
7. Broxmeyer HE, Douglas GW, Hangoc G, et al. Human umbilical cord blood as a potential source of transplantable hematopoietic stem/progenitor cells. *Proc Natl Acad Sci U S A.* 1989; 86:3828-3832.
8. Gluckman E, Broxmeyer HE, Auerbach AD, et al. Hematopoietic reconstitution in a patient with Fanconi's anemia by means

of umbilical cord blood from a HLA identical sibling. *N Engl J Med.* 1989;321:1174-1178.
9. Kurtzberg J, Laughlin M, Graham ML, et al. Placental blood as source of hematopoietic stem cells for transplantation into unrelated recipients. *N Engl J Med.* 1996;353:157-166.
10. Rubinstein P, Carrier C, Scaradavou A, et al. Outcomes among 562 recipients of placental blood transplants from unrelated donors. *N Engl J Med.* 1998;339:1565-1578.
11. Locatelli F, Rocha V, Chastang C, et al. Factors associated with outcome after cord blood transplantation in children with acute leukemia. *Blood.* 1999;93:3662-3671.
12. Gluckman E. Current status of umbilical cord blood hematopoietic stem cell transplantation. *Exp Hematol.* 2000;28:1197-1205.
13. Wagner JE, Barker JN, DeFor TE, et al. Transplantation of unrelated donor umbilical cord blood in 102 patients with malignant and nonmalignant diseases: influence of CD 34 cell dose and HLA disparity of treatment-related mortality and survival. *Blood.* 2002;100:1611-1617.
14. Sanz GF, Saavedra S, Planelles D, et al. Standardized, unrelated donor cord blood transplantation in adults with hematologic malignancies. *Blood.* 2001;98:2332-2338.
15. Laughlin MJ, Barker J, Bambach B, et al. Hematopoietic engraftment and survival in adult recipients of umbilical cord blood from unrelated donors. *N Engl J Med.* 2001;344:1815-1822.
16. Ooi J, Iseki T, Takahashi S, et al. A clinical comparison of unrelated cord blood transplantation and unrelated bone marrow transplantation for adult patients with acute leukaemia in complete remission. *Br J Haematol.* 2002;118:140-143.
17. Ballen KK, Wilson M, Wuu J, et al. Bigger is better: predictors of hematopoietic potential of umbilical cord blood units. *Bone Marrow Transplant.* 2001;27:7-14.
18. Ballen KK, Broxmeyer HE, McCullough J, et al. Current status of cord blood banking and transplantation in the United States and Europe. *Biol Blood Marrow Transplant.* 2001;7:635-642.
19. Sirchia G, Rebulla P, Lecchi L, et al. Implementation of a quality system (ISO 9000 series) for placental blood banking. *J Hematother.* 1998;7:19-35.
20. Kogler G, Callejas J, Hakenberg P, et al. Hematopoietic transplant potential of unrelated cord blood: critical issues. *J Hematother.* 1995;5:105-116.
21. Wagner JE, Kurtzberg J. Banking and transplantation of unrelated donor umbilical cord blood: status of the National Heart, Lung, and Blood Institute-sponsored trial. *Transfusion.* 1998; 38:807-809.
22. Ballen KK, Hicks J, Dharan B, et al. Racial and ethnic composition of volunteer cord blood donors: comparison with volunteer unrelated marrow donors. *Transfusion.* 2002;42:1279-1284.
23. Lasky LC, Lane TA, Miller JP, et al. In utero or ex utero cord blood collection: which is better? *Transfusion.* 2002;42:1261-1267.
24. Rubinstein P, Dobrilla L, Rosenfield RE, et al. Processing and cryopreservation of placental/umbilical cord blood for unrelated bone marrow reconstitution. *Proc Natl Acad Sci U S A.* 1995;92:10119-10122.
25. Keeney M, Chin-Yee I, Weir K, et al. Single platform flow cytometric absolute CD 34+ cell counts based on the ISHAGE guidelines. International Society of Hematotherapy and Graft Engineering. *Cytometry.* 1998;34:61-70.
26. Sutherland DR, Anderson L, Keeney M, et al. The ISHAGE guidelines for CD 34+ cell determination by flow cytometry. International Society of Hematotherapy and Graft Engineering. *J Hematother.* 1996;3:213-226.
27. Armitage S, Warwick R, Fehily D, et al. Cord blood banking in London: the first 1000 collections. *Bone Marrow Transplant.* 1999;24:139-145.
28. Baxter-Lowe LA, Kim Y, Carter S, et al. Ability of minority patients to find donors from an ethnically diverse cord blood bank. *Blood.* 2002;100:2521a (abstr.).
29. Spigner C, Weaver M, Cardenas V, et al. Organ donation and transplantation: ethnic differences in knowledge and opinion among urban high school students. *Ethn Health.* 2002;7:87-101.
30. Rozon-Solomon M, Burrows L. 'Tis better to receive than to give: the relative failure of the African American community to provide organs for transplantation. *Mt Sinai J Med.* 1999;66: 273-276.
31. Daniels DE, Smith K, Parks-Thomas T, et al. Organ and tissue donation: are minorities willing to donate? *Ann Transplant.* 1998;3:22-24.
32. Moroff G, Seetharaman S, Kurtz J, et al. Multi-laboratory evaluation of assays utilized with cord blood stem/progenitor cells. *Blood.* 2002;100:617a (abstr.).
33. Stewart SL, Swallen KC, Glaser SL, et al. Comparison of methods for classifying Hispanic ethnicity in a population-based cancer registry. *Am J Epidemiol.* 1999;149:1063-1071.
34. Kaplan JB, Bennett T. Use of race and ethnicity in biomedical publication. *JAMA.* 2003;289:2709-2716.
35. Serna DS, Lee SJ, Zhang M, et al. Trends in survival rates after allogeneic hematopoietic stem cell transplantation for acute and chronic leukemia by ethnicity in the United States and Canada. *J Clin Oncol.* 2003;20:3754-3760.